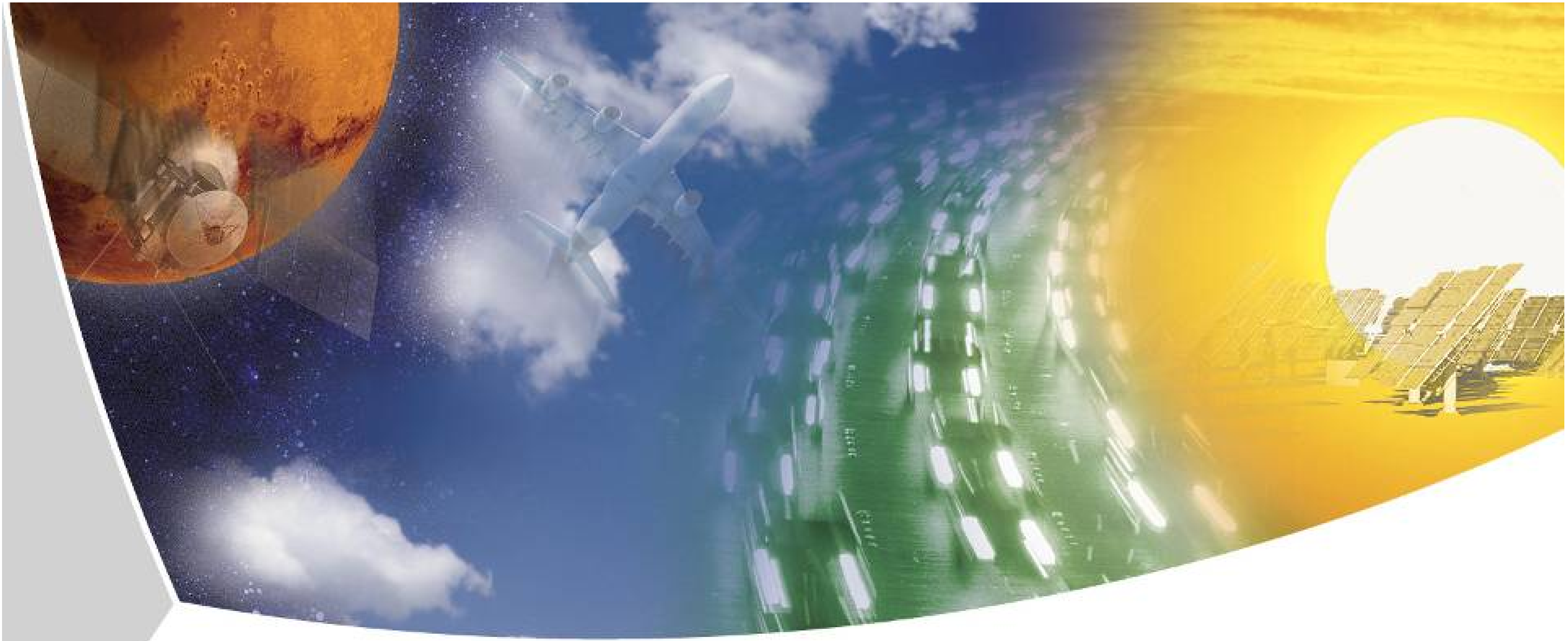
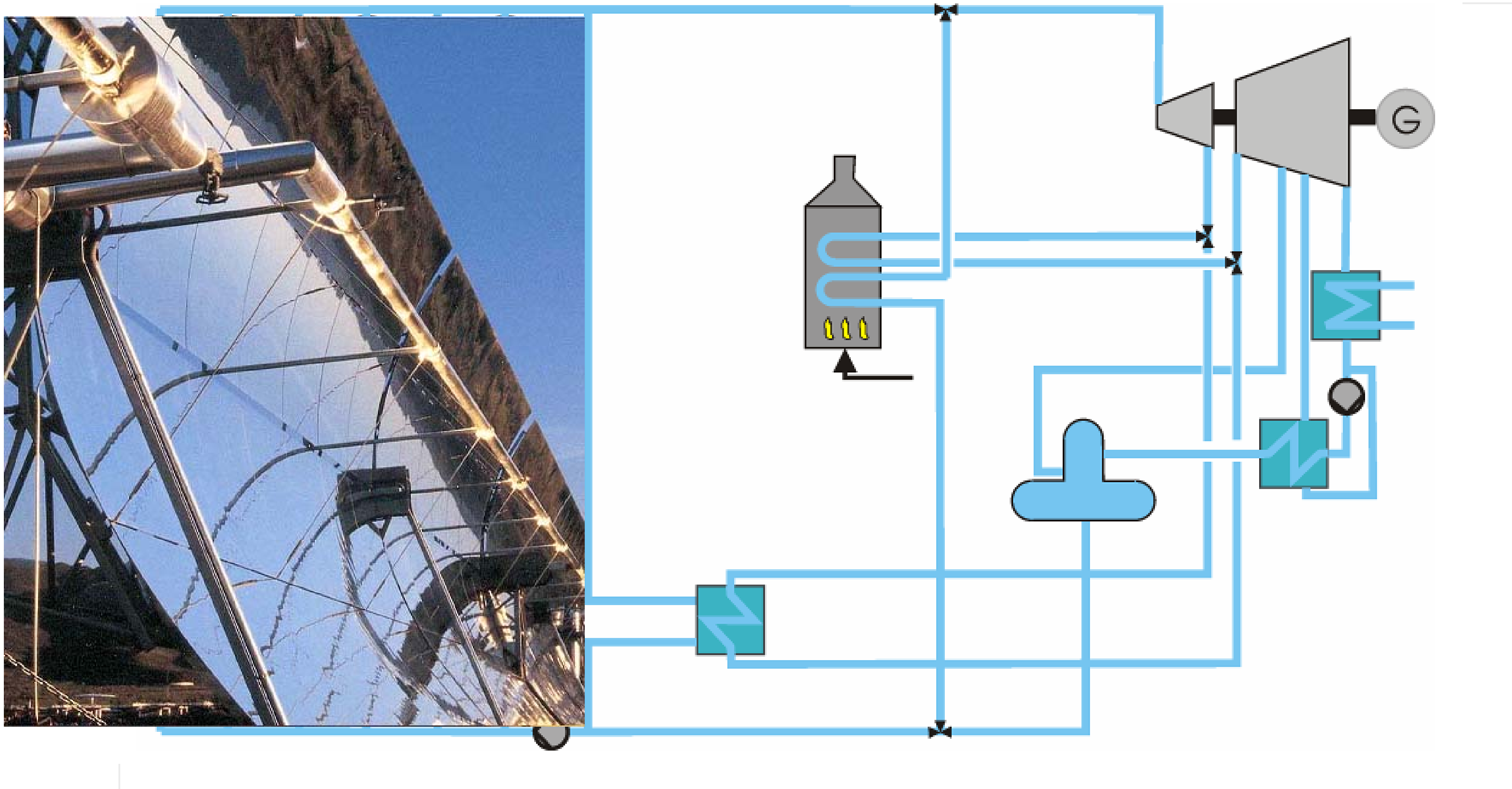


Next Generation Technologies for solar thermal electricity production

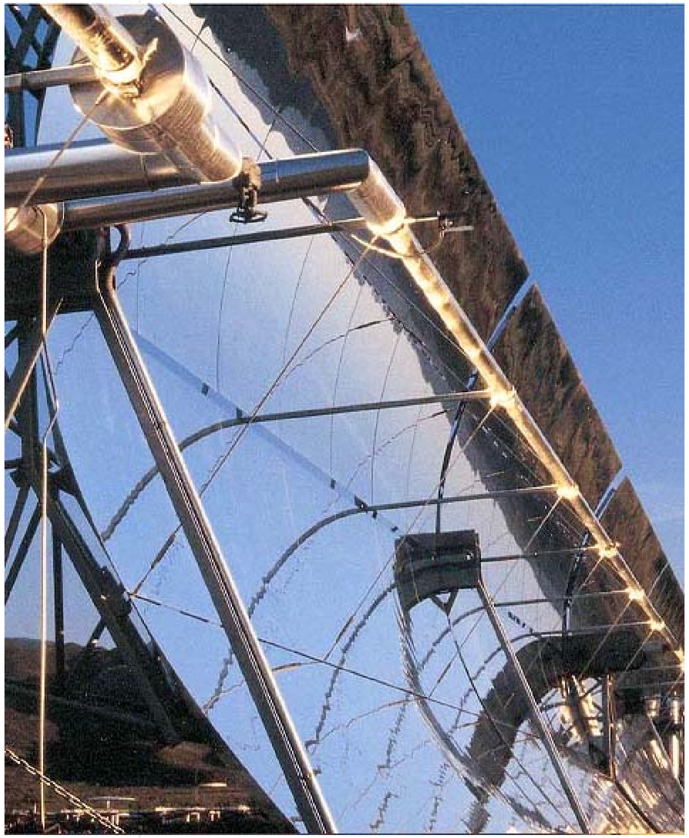
Robert Pitz-Paal, DLR

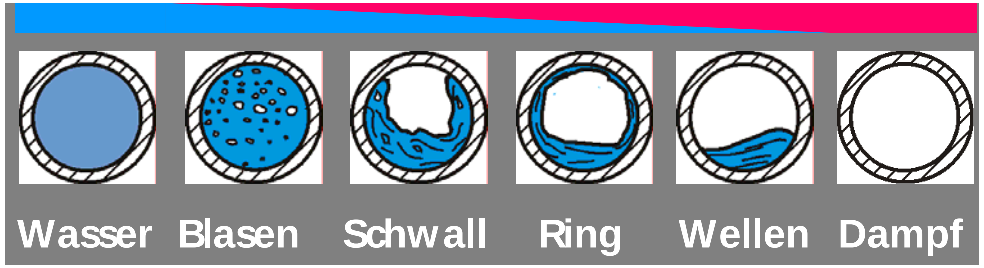
DLR Deutsches Zentrum für Luft- und Raumfahrt e.V.
in der Helmholtz-Gemeinschaft

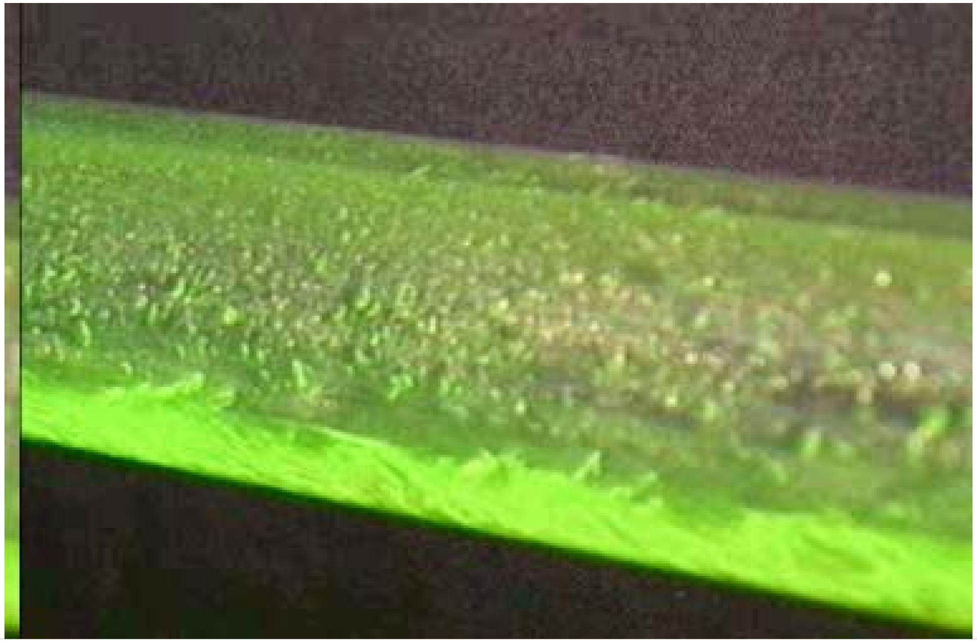
Direct Solar Steam Generation



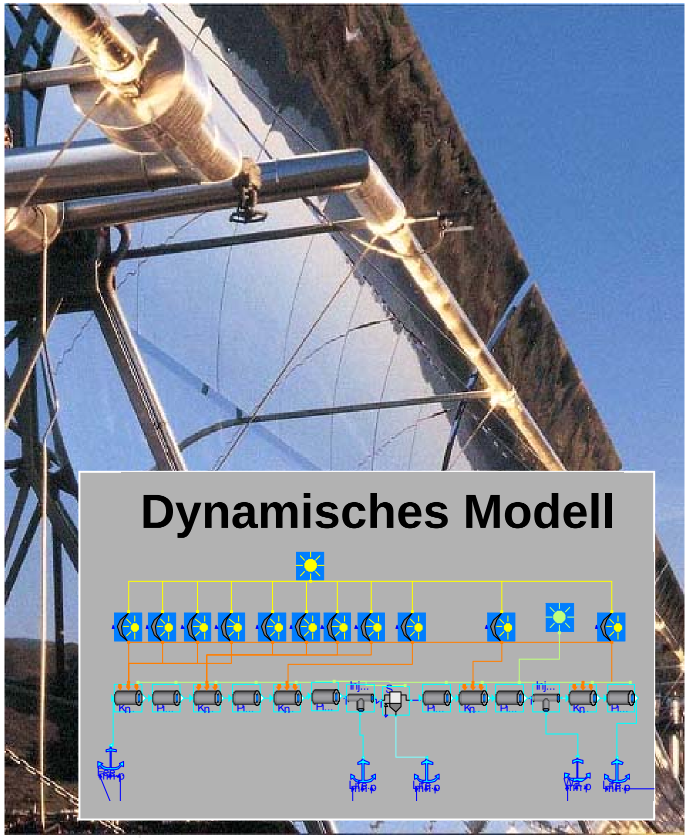
Direct Solar Steam Generation
Thermo-hydraulics

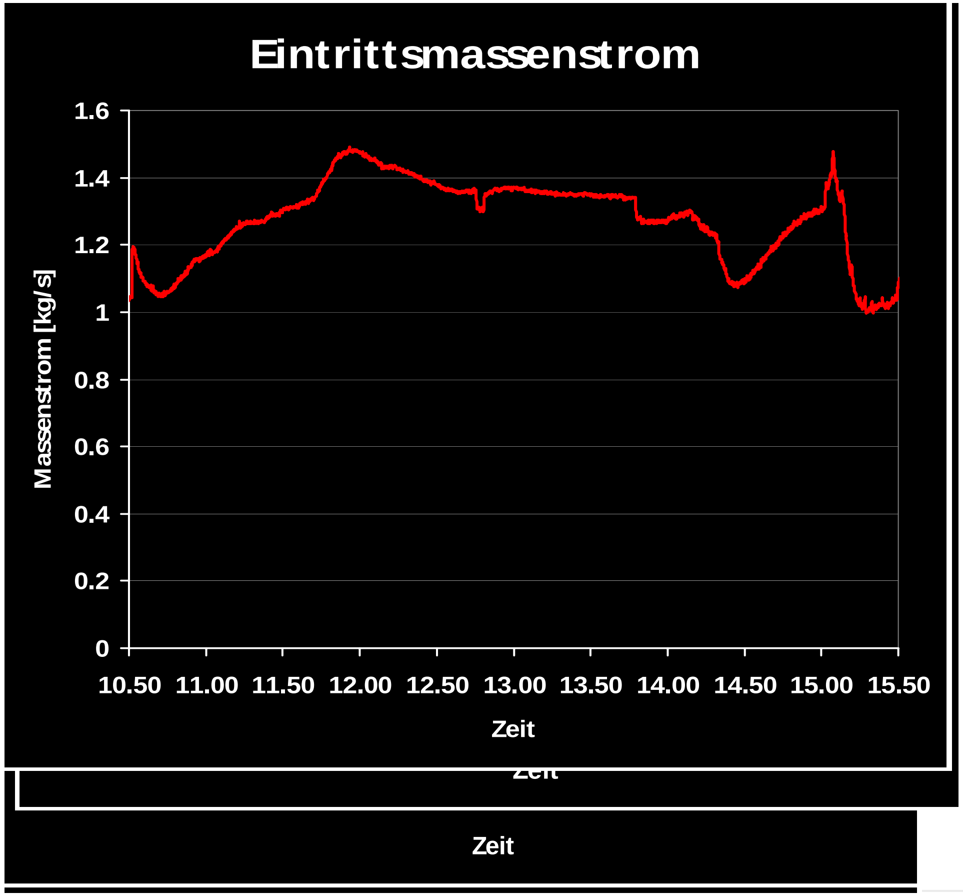




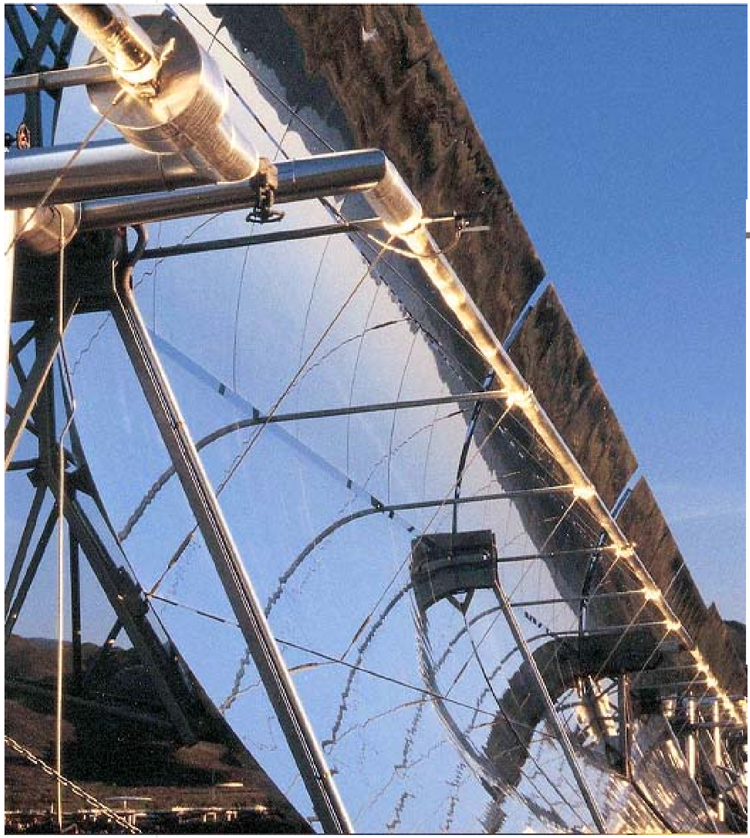


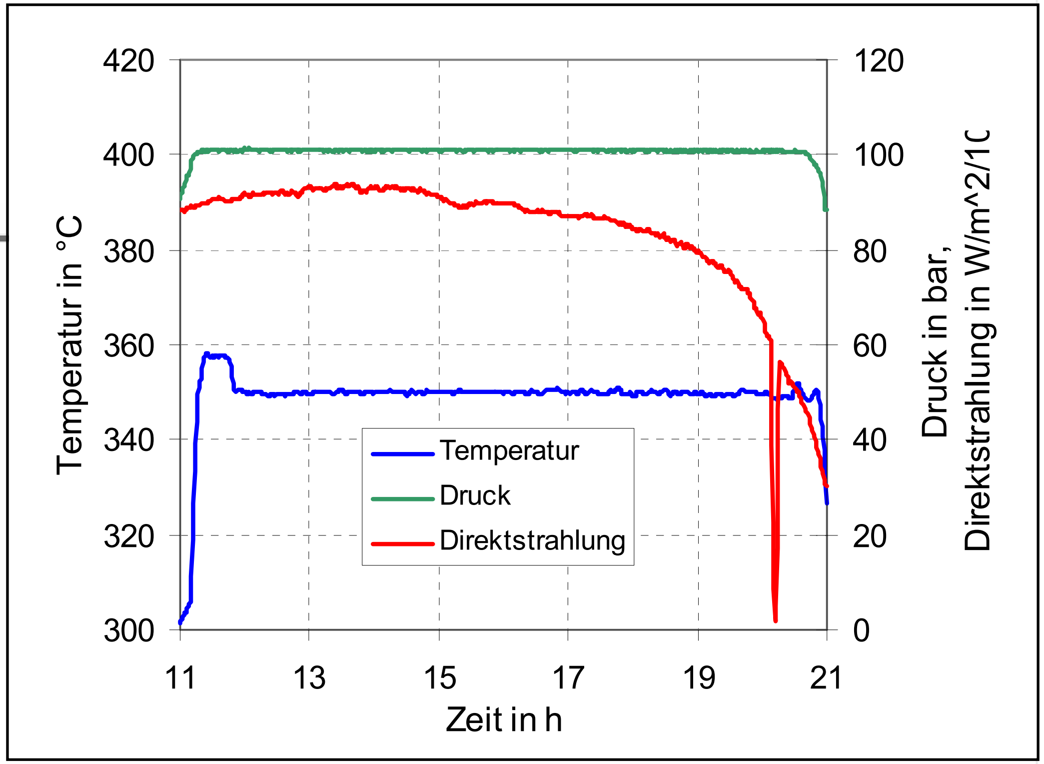
Direct Solar Steam Generation
Control



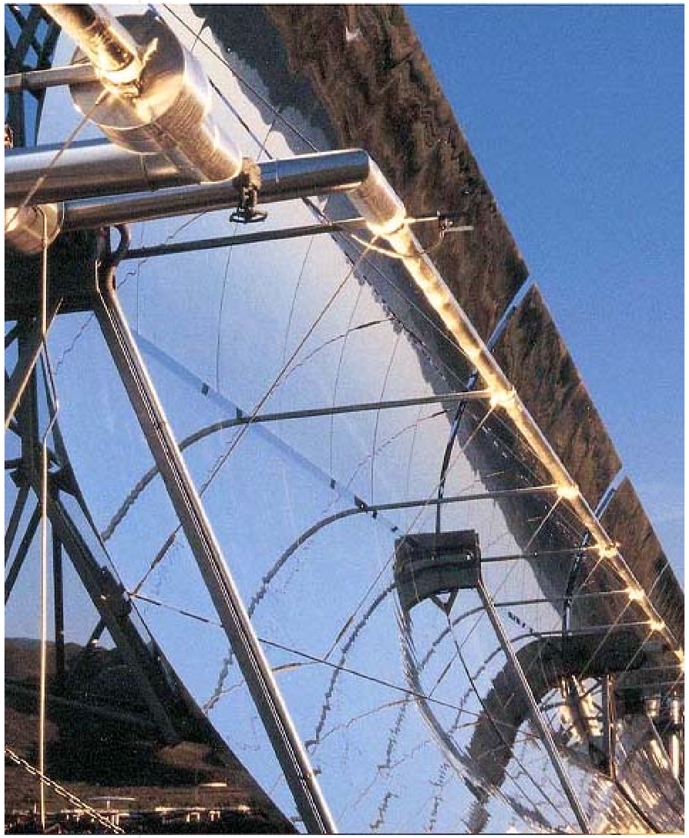


Direct Solar Steam Generation
Control

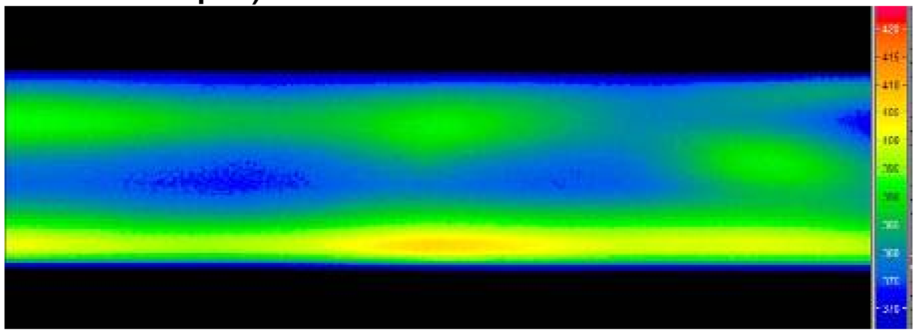




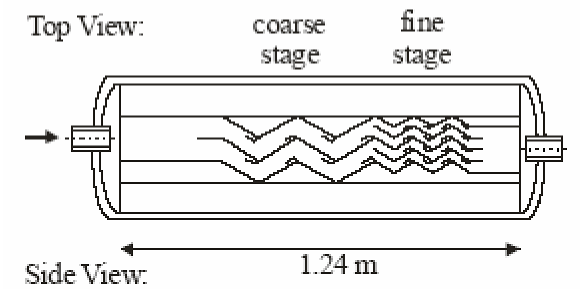
Direct Solar Steam Generation
Component Optimization



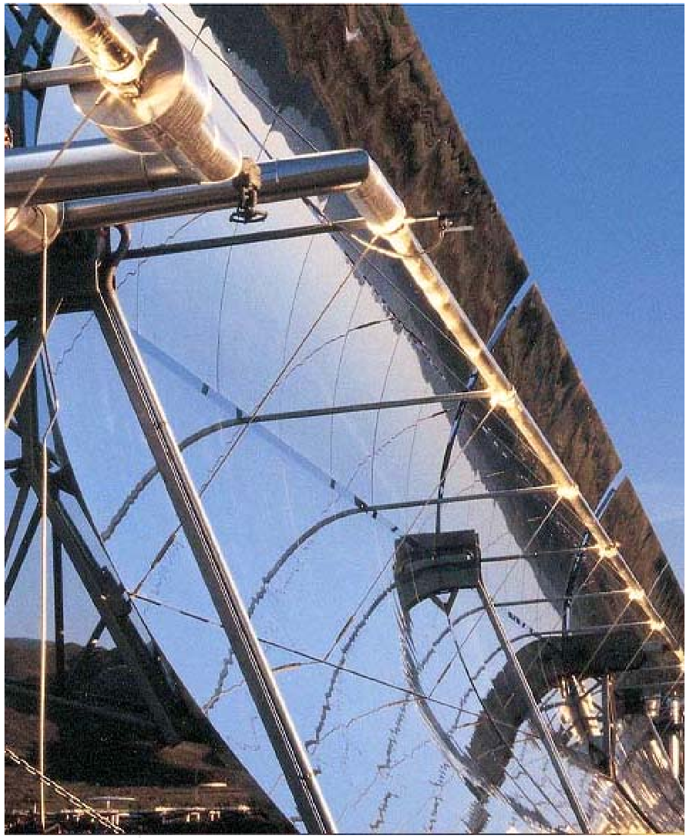
- Absorber Tube (Temperature Image through glass envelope)

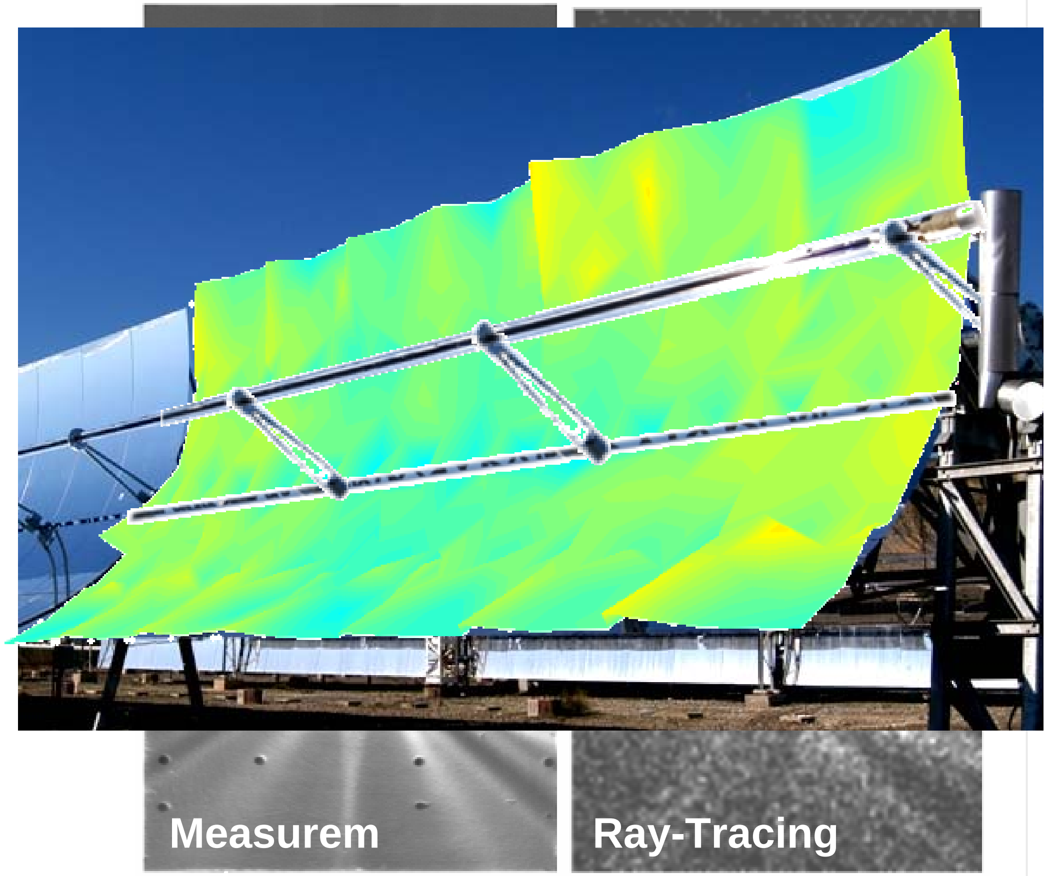


- Compact-Steam Seperators



Direct Solar Steam Generation
Qualification

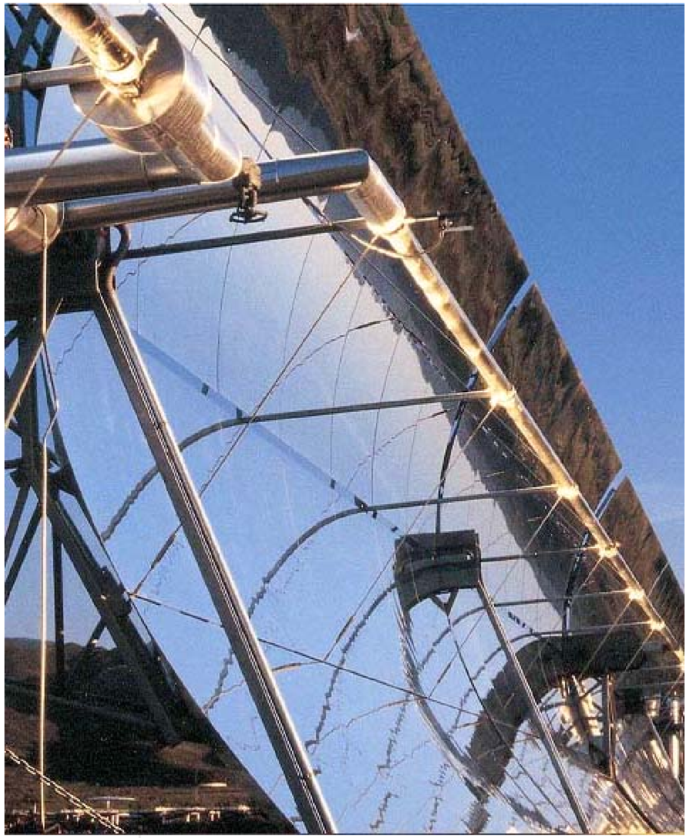


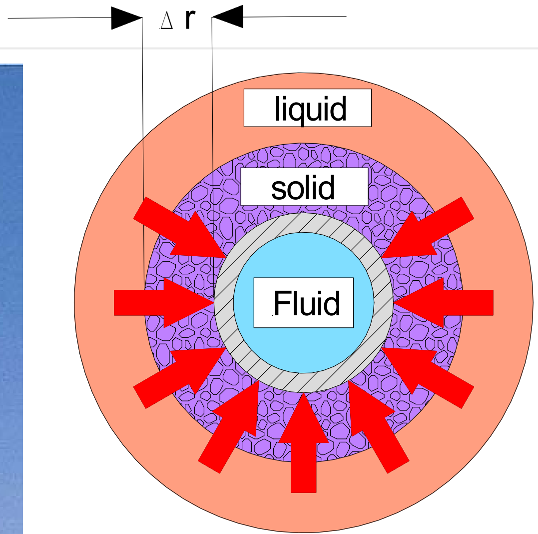


Flux distribution next to absorber tube

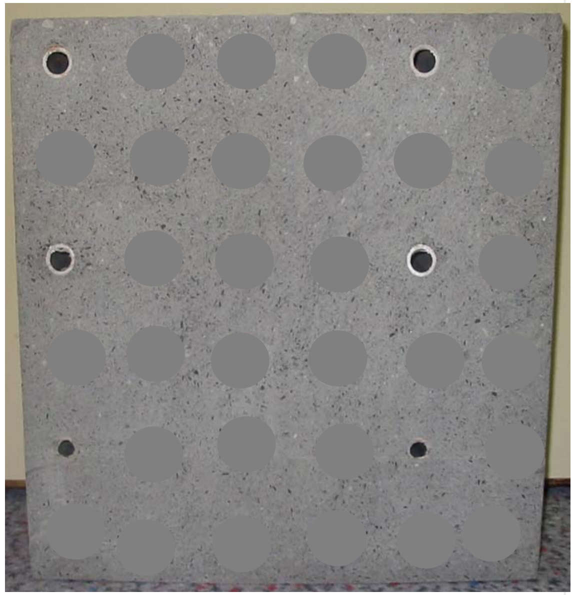
Direct Solar Steam Generation

Latent Heat Storage Technology

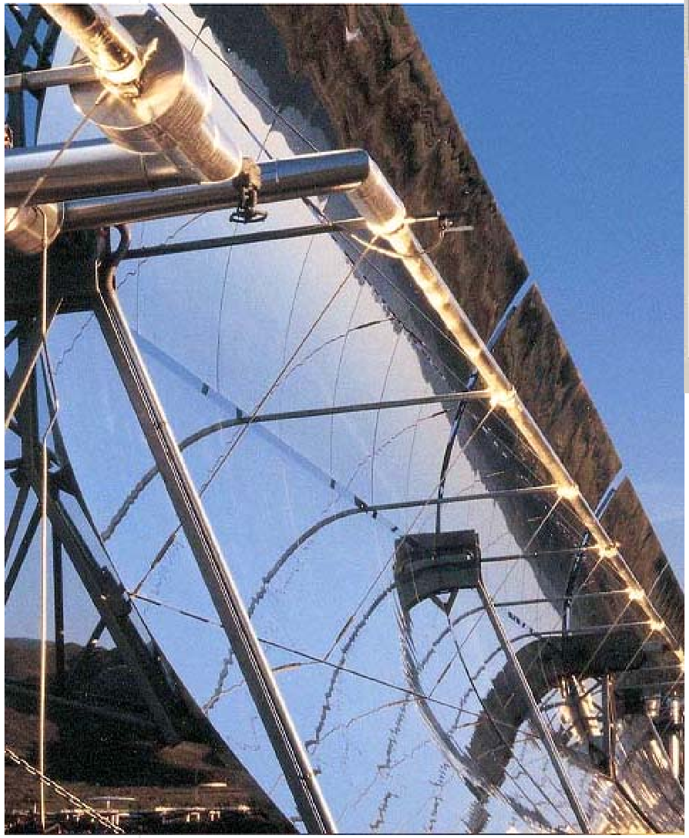


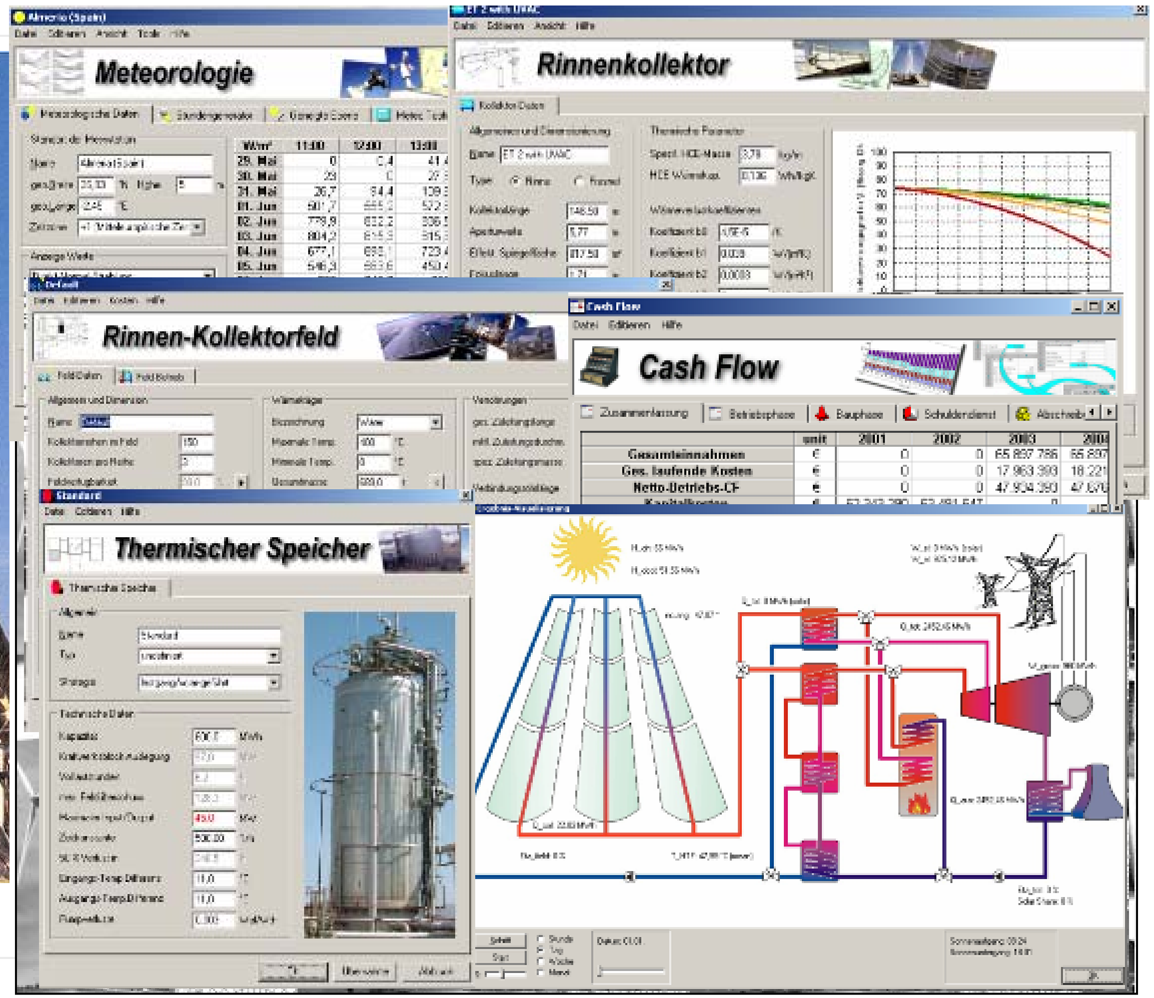


Latentspeicherung
durch Phasenwechsel
in der Salzschmelze

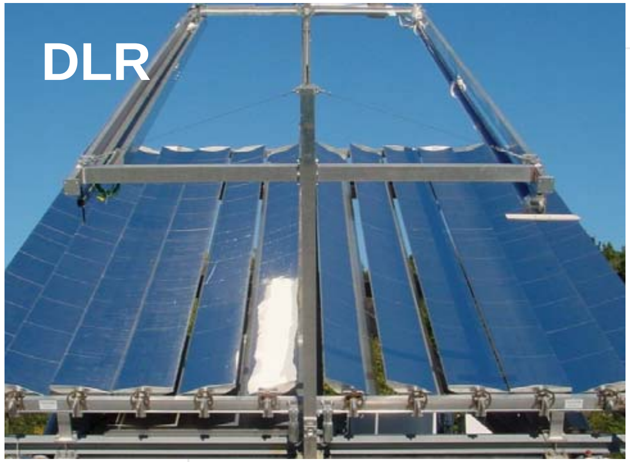


Direct Solar Steam Generation
System Optimization





A few words on Linear Fresnel Systems

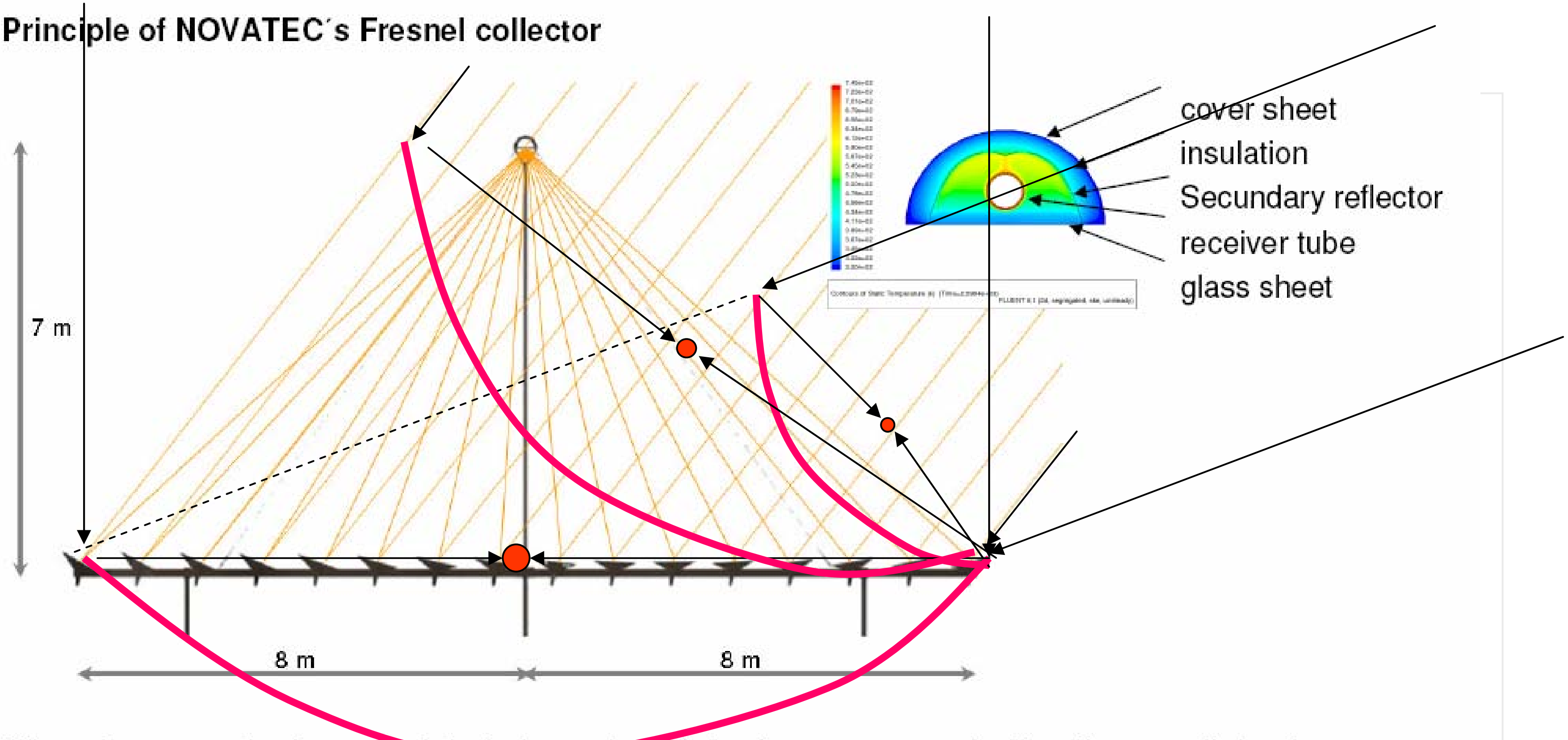


The Linear Fresnel Design

- More simple design offers potentially lower investment cost
- Lower optical efficiency compared to parabolic troughs
- Therefore, high optical accuracy required

NOVATEC BioSol AG

Principle of NOVATEC´s Fresnel collector

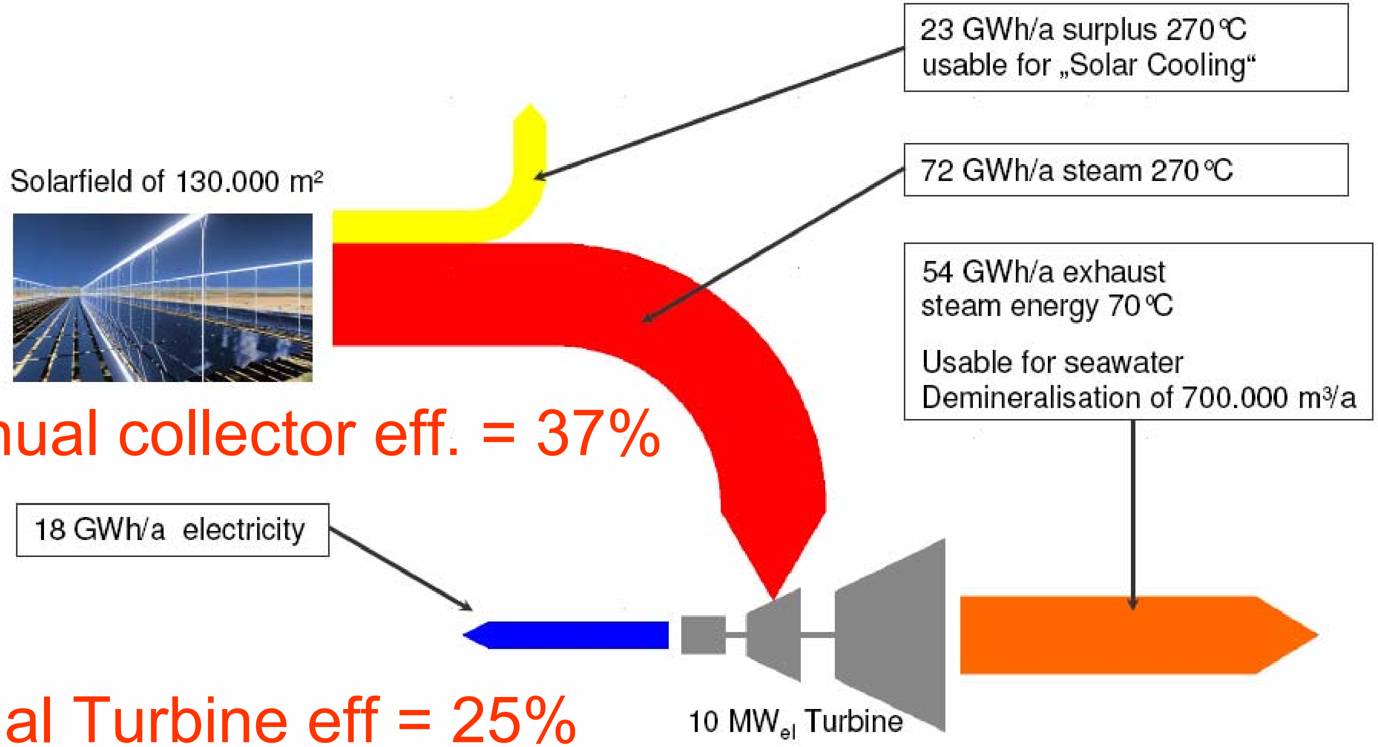


The steam producing principle is based on flat mirrors, concentrating the parallel solar radiation on a receiver tube. Inside the tube water is vaporised and directed to steam turbine

NOVATEC BioSol AG

NOVATEC BioSol– energy flow of a 10 MW Solar power plant

Beside production of electricity the surplus and exhaust thermal power can be used for chill production and seawater demineralisation.



Annual collector eff. = 37%

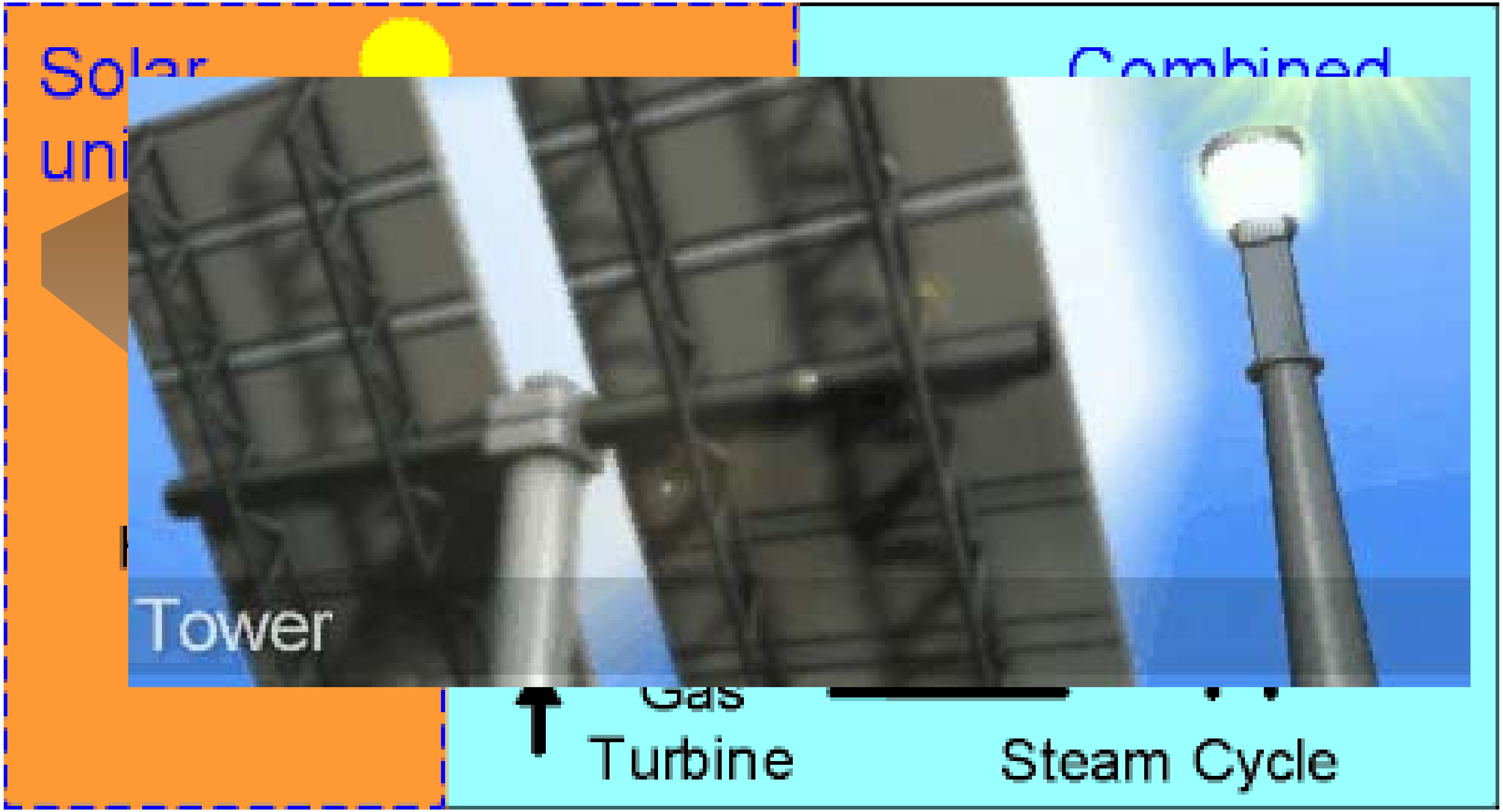
Annual Turbine eff = 25%

- company factsheet -

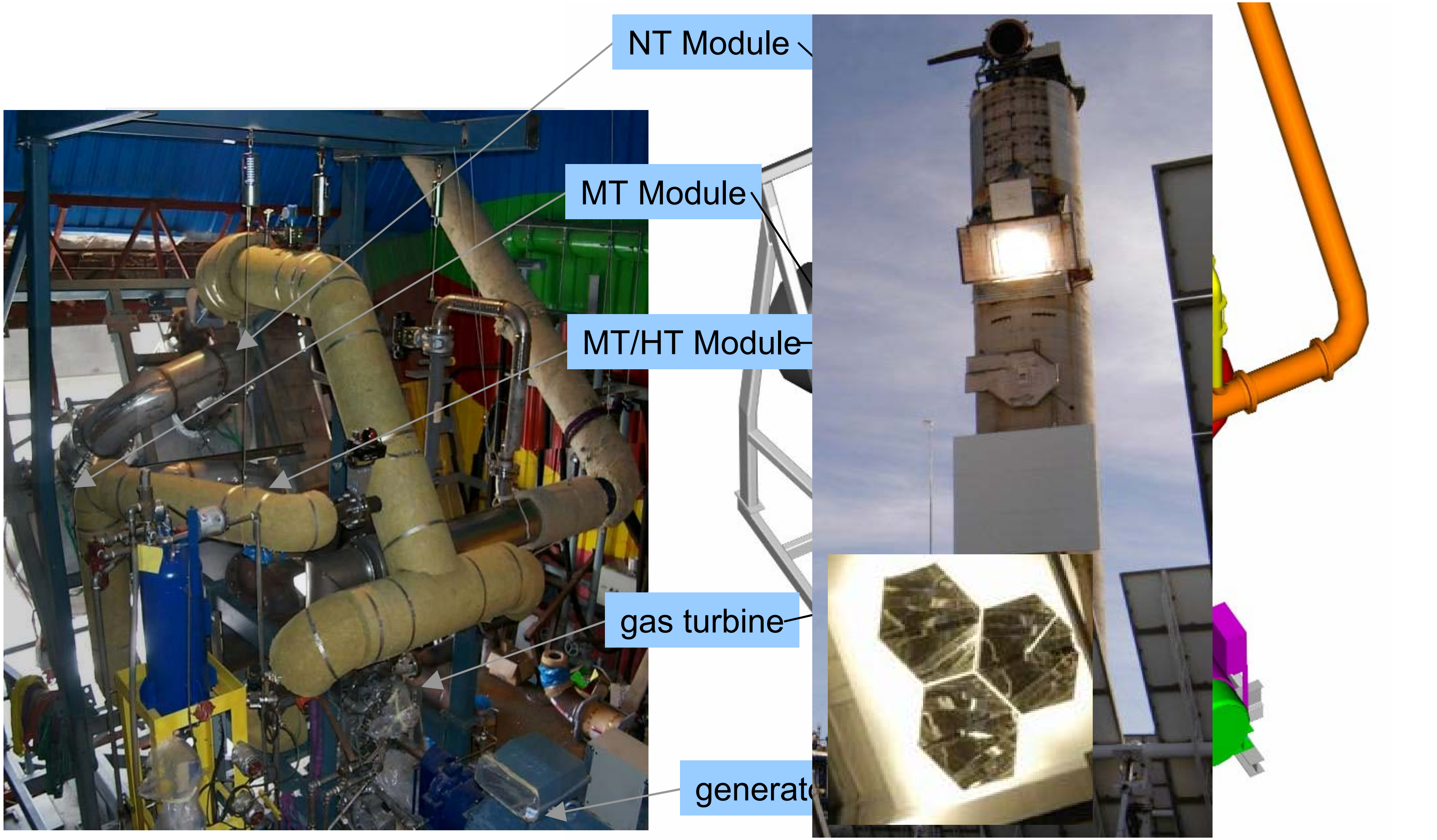
Fresnel Total Annual Eff. = 9%

Trough/Tower > 15%

The Solar Gas Turbine Approach

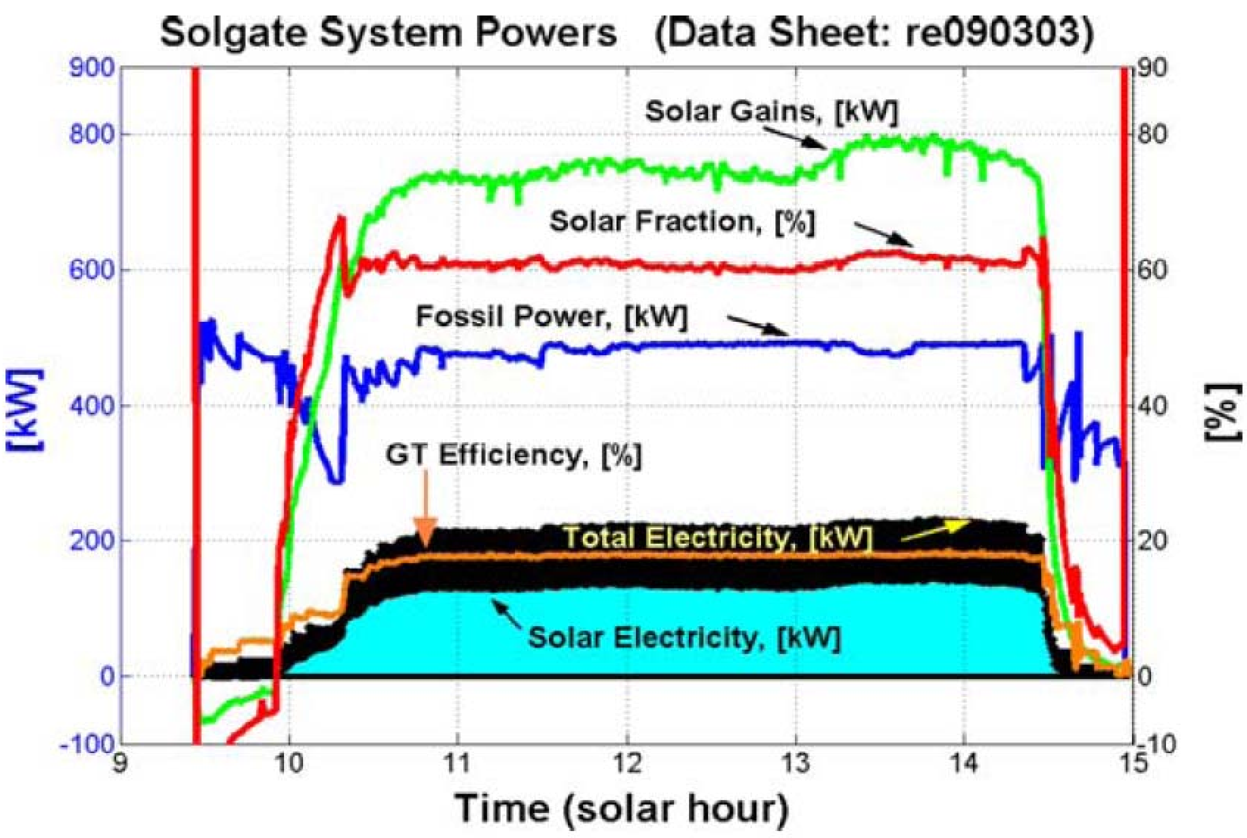


Experimental Experience at the PSA

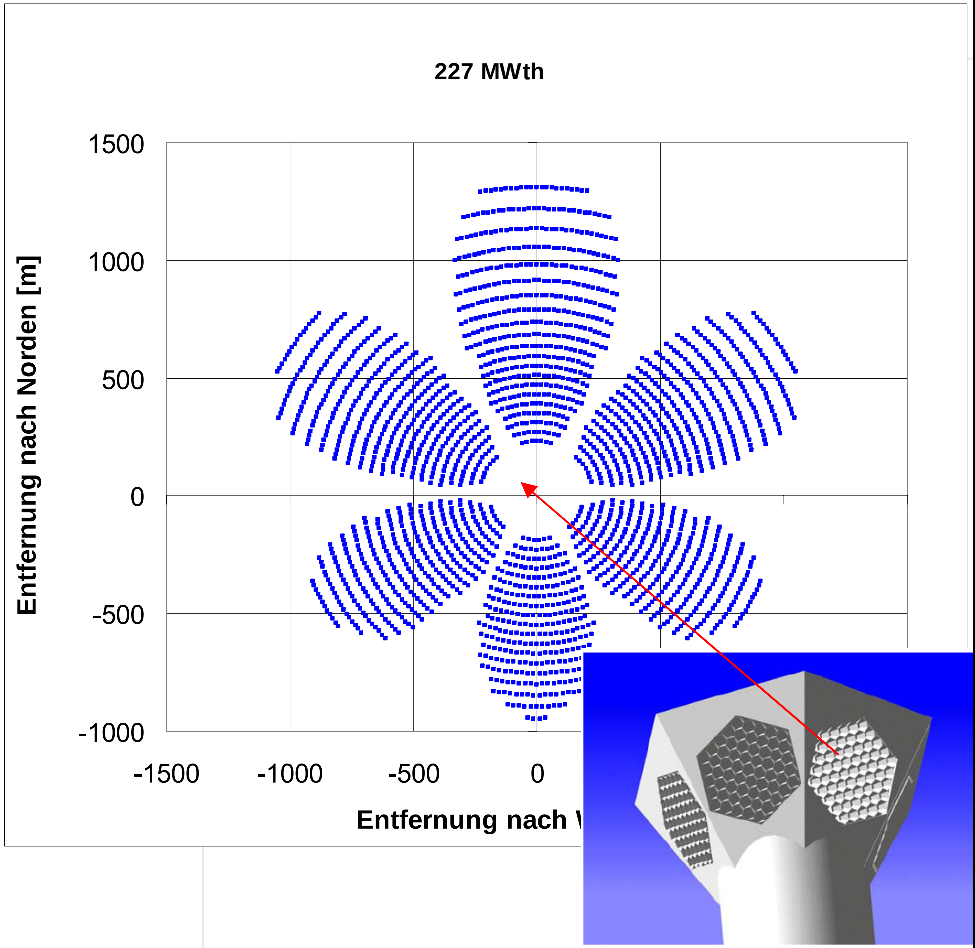


Experimental Experience at the PSA using a small gas turbine

- Feasibility shown how to integrate solar high temperature heat a 800°C; 7 bar into a gas turbine
- Solar share up to 68%
- Good controllability at fluctuating irradiation
- Receiver exit temperature of >1000°C demonstrated
- Performance figures of design tools confirmed



Long-term concept for a solar-fossil Combined-Cycle



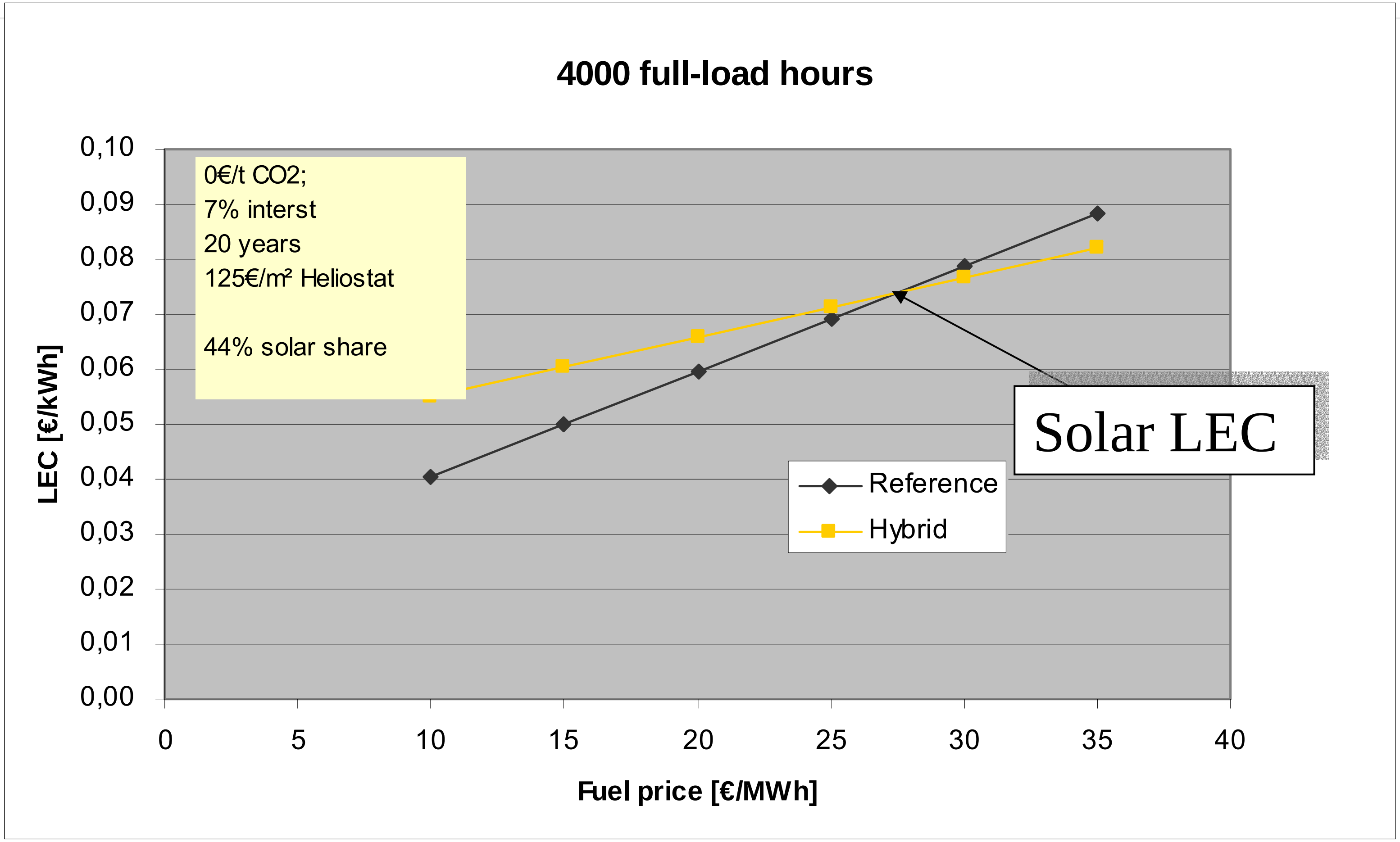
Power block		
Gas turbine (2 * V64.3)	kWe (ISO)	2 * 60’533
Steam turbine	kWe (ISO)	62’400
Total Power (design point DP)	kWe (DP)	158’900
Gas turbine inlet temperature	°C	1250
Annual power cycle efficiency	%	49.4/52.2
Solar-System		
solar input (DP)	W/m²	880
number of heliostats	-	2379
Total reflective area	m²	499’495
rec. outlet temperature (DP)	°C	1100
aperture of single module	m²	1,28
total receiver aperture	m²	734,4
number of rec. modules		572
total receiver power	kWth	227’000
Optical tower height	m	220,0
Annual solar to heat eff.	%	41.4

Cost assumptions Investment

- „Levelized Electricity Cost (LEC)“ based on IEA method
- Interest rate 7%
- Depreciation time 20 a
- site Barstow (California, USA)
- Annual direct irradiation 2791 kWh/m²a
- Fuel price varied (today arround17 €/MWh in US)

Power cycle		Solar	Reference
Power cycle	[T€]	88.300	81.800
Fuel system	[T€]	6.500	6.500
Grid connection	[T€]	2.250	2.250
Total	[T€]	97.050	90.550
Specific (related to. DP-power)	[€/kWe]	611	570
Solar-System			
heliostat field (125€/m²)	[T€]	62.437	
tower (220 m)	[T€]	4.475	
receiver (35 T€/m²)	[T€]	23.876	
control	[T€]	1.000	
Total	[T€]	91.788	-
Specific	[€/kWth]	404	-
Additional Investment		Solar	Reference
Site preparation	[T€]	4.495	
Buildings	[T€]	300	125
Electrical equipment	[T€]	250	100
Auxiliary equipment	[T€]	150	50
Total	[T€]	5.195	275
Indirect cost			
Construction (9%)	[T€]	17.463	8.174
Management (10%)	[T€]	19.403	9.083
Contingencies (3.5%)	[T€]	7.761	3.633
Total	[T€]	42.062	17.532
Total	[T€]	236.095	108.357
Specific (related to. DP-power)	[€/kWe]	1.486	682

LEC in Mid-load Operation



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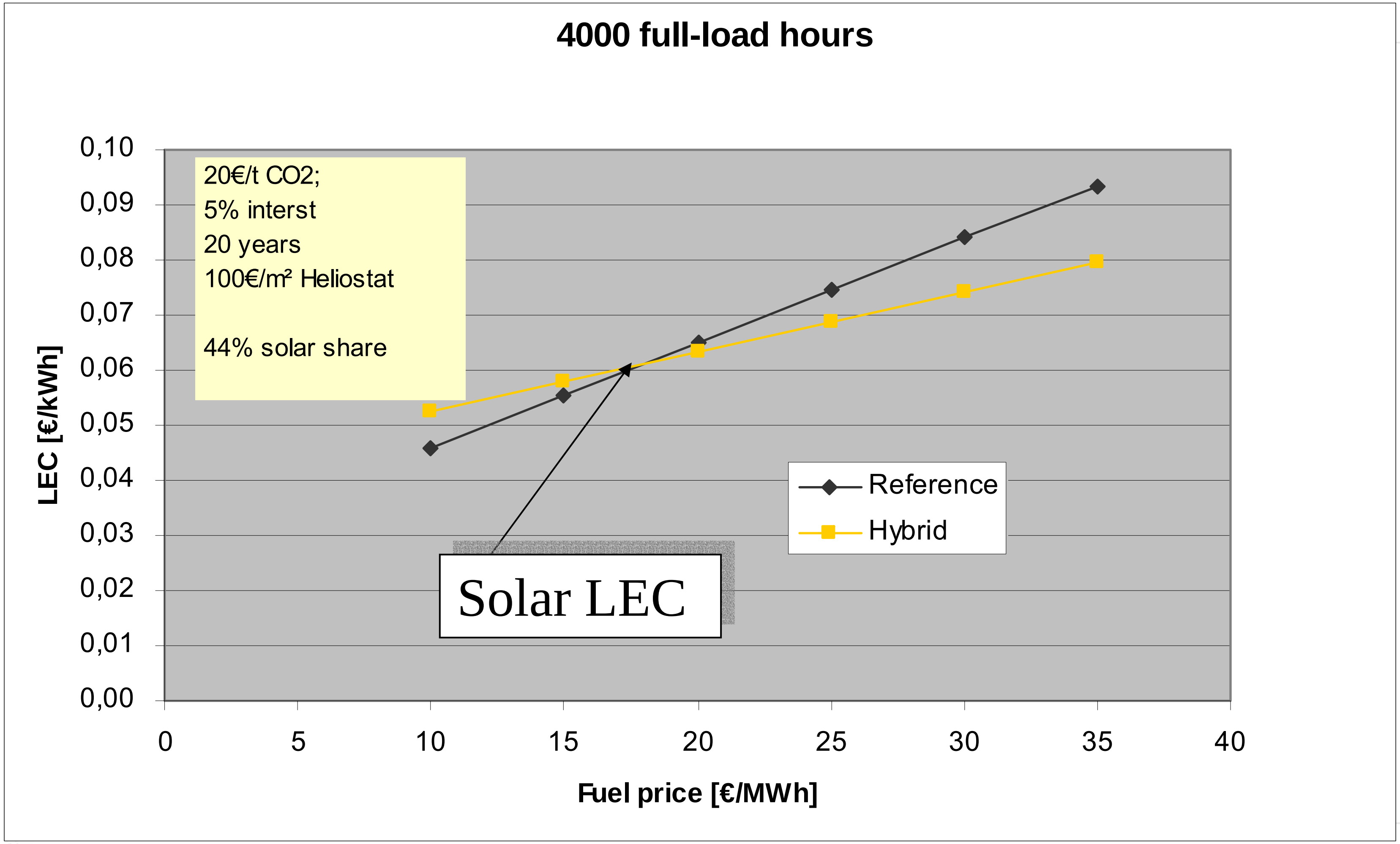
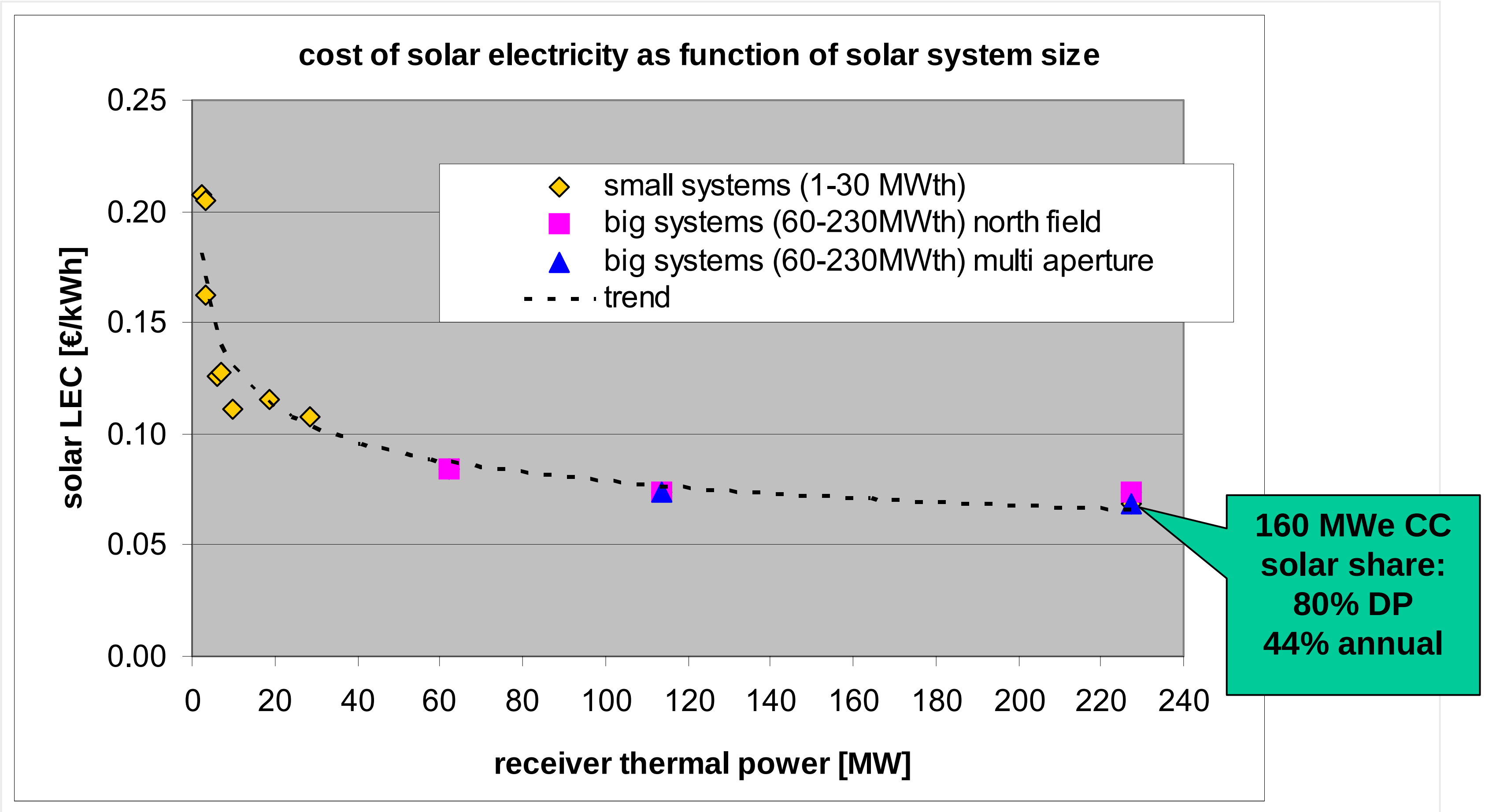
Impact of CO2-penalties, interest rate and heliostat cost



How to go there…



Summary

- High efficient solar power plant for mid-load power
  - Solar-to–electric efficiencies > 20%
  - Fuel-to-electric efficiency > 50%
- Low environmental profile
  - 25% of cooling water compared to parabolic trough plant
  - No thermal oil!
  - Can be applied in hilly area
- Low cost
  - Specific investment cost <1500 €/kWe
  - LEC = 7 €cent/kWh for 160 MWe power plant
- Scale-up
  - Starting with small turbines (eventually combined with CHP)
  - Hybridization with Biofuel (up to 50% feasible in Spain)

Thank you for your attention!